EXAMINING CURRENT CONCEPTS IN ECOLOGY

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A NATO workshop held at Grange-over-Sands, Cumbria United Kingdom in 1983 examined Formal Concepts of Ecology in the Eighties in order to establish a working list of ecological principles. The collected principles from workshop discussion were the accepted concepts established by invited participants selected for the study from numerous countries and supporting disciplines of ecology. After we identified current principles, individual workshop participants should further examine the current concepts. Statements must be justified within all disciplines of science in order to warrant their existence.

Ecology principles are based on interactions between organisms and other organisms, organisms and the abiotic environment, and the abiotic environment and the organisms. Variation in efficiency in utilizing available resources is as diverse as the total number of existing life forms. More efficient biotypes gain advantages over other life forms and those less efficient may diminish or even face extinction. Currently successful biotypes could ultimately become a future resource for other organisms. A general establishment of ecological thought was collected by the participants representing varied academic backgrounds, training, and experience, from numerous countries and established academic institutions. The collected ecological principles are here briefly examined individually in mycology through training and experiences of one NATO workshop participant.

Justification and Explanation of Ecological Principles:

1. On a global scale, resources are limiting to organisms.

The fungi and other microorganisms will not grow, reproduce or survive if resources required by microbial species for growth, reproduction and survival are lacking.

1.a. There is a minimum resource set (energy and chemical elements) required by all life processes.

There is a minimum, optimum, and maximum quantity of C, N, minerals, and vitamins for each microbial species. Each species differs from other species as to their nutrient sources and the quantity levels of these sources. Many rust and smut fungi are host species specific, some requiring two specific hosts to complete a life cycle that spans two years. The habitat for these Uredinales and Ustilaginales is limited to the habitat of their plant hosts. Nutritional requirements and environmental limitations are highly specific for these fungi. Other fungi such as species of the Deuteromycetes have a broad nutrient spectrum suitable to support growth of the species. Such species are world wide in distribution and are found in many diverse climatic regions.

1.b. A functional individual of any species requires minimal amounts of these resources for existence.

When optimum nutrient levels as well as environmental conditions are available to a fungal species, growth occurs with the least stress, and vegetative mycelial growth is generally optimum. At times pleomorphism occurs with the fungal isolate and the vegetative mycelium only produces branching hyphae. Asexual spores such as various types of conidia in terrestrial fungi and zoospores in aquatic species are produced in optimum or nearly optimum growing conditions. As nutrients become limiting and increased growth stress occurs, sexual spores develop such as zygospores, oospores, ascospores, basidiospores, and other meiotic spore types.

Below minimal amounts of required nutrients, growth decreases and cell types such as chlamydospores, racket hyphae, or other vegetative hyphal cells develop within the hyphal colony possessing thick protective cell walls. Sclerotia and stroma also form which are densely formed fungal cell masses composed of pseudoparenchyma and a thick multicellular outer rind to provide additional vegetative methods of surviving unfavorable environmental conditions. Thick walled reproductive cells or tissues are known to survive several years, then they germinate when favorable nutrient and environmental conditions return. If the minimal amounts of required nutrients become nonexistent, and alternate or substitute less efficient nutrients are also unavailable, the fungal species will no longer survive.

1.c. All resource quantities are limited on a global scale.

Each fungal species exists in a defined environment because of the presence of nutrients utilizable by that species and environmental conditions suitable for the existence of the species. The resource quantity is limited in a specific habitat if utilized by the fungi present. Climatic conditions can also limit the usefulness of resources. If the resource is not replinished or made available, each resource will be a limiting factor for fungal survival. On a global scale, resources are not replinished from an extraterrestrial source except for energy of the sun. Fungi are not photosynthetic and thus do not directly require the sun for growth or survival. Some fungal species are photosensitive in the development of cell structures. For example, Pilobolus crystallinus sporangiophores are positively phototropic and sporangia are consequently shot toward light. A pin point light source is great enough to allow sporangial release toward the light to actually hit the point source of light. Light effects growth rate, colony color, colony form, sporulation and discharge of spores, and mutation rate in fungi. However, the lack of light does not terminate fungal growth.

2. The use of resources by organisms changes the resources both quantitatively and qualitatively.

Fungi have the ability to utilize and delete a nutrient from the environment in which they grow. Many fungi utilize high molecular weight carbon sources then store that energy source as a lower molecular weight sugar. The wood rotting fungi such as Polyporus versicolor and Ganoderma applanatum can decompose cellulose of tree xylem, then glucose and other carbon compounds are found within the hyphal cell system of the fungus. Extracellular enzymes decompose the woody material on which the shelf or bracket fungi are attached, then lower molecular weight carbon sources are absorbed into the hyphal cells for use as the energy source for that species.

The synthetic and natural fiber layers and adhesives used in the construction of multilayered Extra Vehicular Activity (EVA) space suits on the Skylab and Soyuz programs were vulnerable to the terrestrial fungus *Chaetomium globosum*. Airborne ascospores and conidia of *C. globosum* can be found world wide. Each layer of the EVA space suit can either support spore germination, hyphal growth, and perithecial ascospore development or allow spores or hyphae to penetrate through the fabric. The U.S. Skylab was launched into orbit fully equipped including the EVA suits of the astronauts selected to inhabit the lab on three successive missions scheduled after the Skylab reached orbit. On arrival, some astronauts found their waiting EVA suits useless due to the heavy initial growth of *C. globosum* and growth of other airborne fungal species and bacteria. Growth of the microorganisms occurred while the EVA suits were stored on board the orbiting Skylab in optimum environmental conditions for the microbes. Contamination occurred from earth air at the time of Skylab liftoff. Some astronauts when reaching the Skylab had to use an undamaged EVA suit individually taylored to another Skylab mission crew member. The EVA space suit presents an example of fungi utilizing nutrients from a substrate on which they are growing to cause changes in the substrate both quantitatively and qualitatively.

2.a. Some organisms modify inorganic chemicals into biochemicals.

The basic requirements of all fungal species include inorganic chemicals. Between 17 and 20 elements are nutritional requirements of the fungi and are utilized in the form of specific compounds, as ions and as elements. Differences in the ability to utilize specific compounds in metabolism or cellular structure in fungal species are quite common. Potassium and magnesium are always found in every fungus mycelium or conidia analyzed, while boron and sodium are less commonly found. However, the mere presence of an element is essential in metabolism or cell structure. Metallic elements known to be essential to fungi generally include potassium, magnesium, iron, zinc, copper, calcium, gallium, manganese, molybdenum, vanadium, and scandium. While it may be assumed that all fungi require the same essential elements, only a limited number of fungi have served as test species in experimentation. The chemicals are incorporated into the fungal structure and either stored or utilized by the fungal cells or tissue.

2.b. Some organisms can use biochemical resources.

Fungi like other microorganisms have the ability to biodegrade an environment by utilizing those nutrients in that environment suitable to maintain growth and survival. Generally an ecological niche will have a dominant species which will be replaced by a second dominant species when the environment becomes limiting for the first species.

A fungal species, such as the mushroom *Agaricus bisporus*, can grow and produce basidiocarps in nature. The basidiocarps at any age can be attacked by insects, other fungi, bacteria, protozoa, and viruses to produce a parasitic relationship. When the basidiocarp dies, other microorganisms invade to establish a saprophytic relationship.

On the other hand, fungi and many other microorganisms produce mycotoxins and other toxic agents that inhibit the growth of other species or cause severe poisoning and death if ingested by animals or humans. Frequently one fungal species will produce more than one toxic agent. Fusarium moniliforme can produce at least seven mycotoxins while 15 chaetoglobosins have been isolated from Chaetomium globosum. The drug industry was dramatically changed by the isolation, purification, and mass production of Penicillium notatum. Microbes utilize and degrade biochemicals and other bioresource systems.

2.c. All organisms need energy to permit modification and maintenance. As energy is both limiting and limited, no one organism can be good at everything.

The ecological niche or habitat is the source of all nutrients required for the survival of all microorganisms. Depending on the microorganism, the supply of energy can be in the form of sunlight, H_2, ammonium, nitrite, an inorganic sulfur compound, ferric iron, or an organic substance. Organic substances suitable as an energy source vary from single elements to complex structures, and this diversity equates the diversity of the hundreds of thousands of microbial species. In addition, microbes inhabit a greater diversity of habitats on earth compared with all other life forms extinct or alive.

3. These changes in resources drive genetic and behavioural changes in organisms to use different quantities and qualities of resources in alternative ways.

Auxotrophic fungal isolates fail to grow on a minimal medium containing the minimum nutrients essential for the growth of the wild type of the species, but will grow if one or more specific substances are added to the medium. When auxotrophs are given their growth requirements, fungal auxotrophs will resemble the wild type in appearance, however, this resemblance is a false representation. Starvation is used for the selection of auxotrophs as has been done with Aspergillus nidulans. In fungi with double mutants of two nutritional deficiencies, survival frequently is longer in minimal medium than the single mutants from which they had been derived. This method serves as an effective method in obtaining auxotrophs in fungi.

3.a. Reproduction and mendelian inheritance occur.

Fungi show great diversity in the asexual and sexual methods of reproduction. Numerous spore types occur in each group of fungi. Although with some difficulty, due to the limitation in cell size and chromosome number, genetic studies can be conducted with fungi. The 'fruit fly' of the fungal world in genetics in Neurospora crassa, commonly known as the red bread mold.

Thousands of species of fungi are placed in the form-class Deuteromycetes because the perfect form of the species does not occur or has been lost with evolution. Reproduction in the Fungi Imperfecti is by asexual methods only and no organized fusion of gametes followed by reduction division and mendelian inheritance occurs. Some of the form-orders belonging to this form-class of fungi include the Moniliales, Sphaeropsidales, and the Melancoiales. Each order contains many genera and numerous species. Asexual methods of reproduction are very effective and allow the organism to survive quite adequately. However, genetic recombination is known to occur in the imperfect fungi by the parasexual cycle in which plasmogamy, karyogamy, and haploidization occurs at any period or age of the organism. No definite pattern of separation or recombination occurs as found in the mendelian processes. All fungi have asexual methods of reproduction including the Deuteromycetes which are characterized by many single celled or multicellular spore or cell forms.

3.b. Variation exists both in space and time in the environment and mutation and recombination of heritability occur.

Microorganisms including most fungi have a rapid production of generations. Some fungi such as the yeasts can complete a generation within a matter of minutes or hours while other fungi require one or two years to complete one life cycle. Within a generation, fungi are extremely prolific in spore production, producing tens of thousands to millions of spores from the initial germination of one spore. Natural variation occurs within spores of one generation to product changes in the next generation such as variation in morphology or growth dynamics, growth rates, structural changes in tissues of the fungus, and changes in virulence or pathogenicity in human, animal or plant mycoses. Some fungi produce all viable spores while others, such as the giant puffball Calvatia gigantea, produce one viable basidiospore in 10,000 to 100,000 spores in nature. Then chance association of Rhodotorula rubra yeast cells with a C. gigantea basidiospore will permit a viable basidiospore to germinate. Frequently fungal spores are destroyed by insects or animals directly feeding upon them or by bacterial invasion reducing the number of spores reaching germination and growth.

In nature mutagenesis occurs by genetic recombination or partial loss of genetic information from one generation to the other. Mutagenic agents in the environment include the presence of chemicals or environmental change by temperature, moisture, and light. The greatest mutagenicity with light in fungi occurs at 254 nm which is always present in the sun light spectrum. With the high production of spores, a complete range of change occurs with each parameter in a fungal species. Some mutagenesis is great enough to cause immediate death to the cell while the same mutagenesis in other like cells could be so subtile that the effects can not be detected. Both genotypic and phenotypic changes occur with about the same degree of frequency in the fungi that the effect produces constant change within a species.

3.c. Darwin's principle of natural selection follows from the above statements. More efficient individual organisms will persist while less efficient organisms will be eliminated. These processes inherently lead to specializations in resource use.

The use of resources or nutrients by a fungus is generally quite species specific. In bacterial taxonomy, the identification of an isolate in pure culture is totally dependent on chemical methods, primarily by the utilization of C and N sources under aerobic or anaerobic conditions. Morphological differences at the macroscopic and microscopic levels are the methods of fungal identification, however, fungal genera and species register their own identifications in quality and quantity of specific nutrients. A phenotypic or genotypic change in a fungal species could interrupt the efficiency of utilizing specific nutrients and less frequently dramatically changes the dietary requirements of that fungal species. Mutagenic changes generally produce less efficieny in resource use in fungi and a more narrow degree of tolerance. Bacterial isolates within one species also vary in their chemical characteristics according to source of isolation, age of the culture, and other physical factors which increases difficulty in accurate species identification.

4. In very simple systems, natural selection causes positive feedback and hence increases qualitative and quantitative variations of available resources.

As variation in organism type increases, the likelihood of successful new specialist variants decreases because the chances of finding enough of a "super-specialized resource" for maintenance and growth becomes vanishingly small.

Fungi become less tolerant of environmental or nutrient change as mutations increase within a species. Phenotypic or genotypic change brings stress to the mutated species that causes the changed organism less adaptability to the niche in which it was growing.

The nematode destroying fungus Arthrobotrys oligospora and the rust fungus Gymnosporangium juniperi-virginianae are host specific to which the fungal species attacks or parasitizes. Changes in the fungal isolate reduces the pathogenicity but generally does not increase the number of hosts on which the isolate can grow. Fungal species that are both parasitic and saprophytic in nature have a broad range of environments and a wide selection of nutrients to support life of the fungus. Change in fungi is far less detrimental to the survival of facultative parasites than obligate species.

5. As the variation in organisms increases there is a greater chance that more complex structural organizations and interactions will occur.

Increase in tissue complexity and cellular types in fungal species generally increases selectivity in the habitat they occupy. Fungi having a large number of sexual and asexual reproductive cell types and complex reproductive structures are also limited to specific habitats and generally a reduced time of a specific spore production. A species having only one asexual conidial form produces an abundance of reproductive cells over a long time period in the life cycle and generally the species has numerous environmental conditions and ecological niches suitable to support growth.

5.a. As the variation in organisms increases, there is a higher probability of an increase in their organization through sequential aggregation into colonies, populations, communities and ecosystems.

Microbes including fungi are self sufficient, and generally grow quite independent from other species except for the obligate pathogens. Only a limited number of all fungal species are obligate parasites or symbiotic with another organism, but their degree of specialty in growth relations does not increase the complexity in cell structure of the fungus. Obligate parasites have the same structures as facultative species in the same genus, and symbiotic species are also similar in structure as independent isolates. A better growth efficiency but a more specialized niche exists for obligate parasites and symbiotic fungi.

The evolution of slime molds or Myxomycetes such as Stemonitis splendens best fits this ecological concept. Uninucleate and independent myxamoebae are chemotactically attracted toward each other to form an aggregate of myxamoebae or plasmodium. The multinucleate plasmodium feeds upon the substrate of decaying wood and leaf litter to gradually increase in size and continue the mitotic nuclear divisions. Obtaining a suitable size, the plasmodium begins to differentiate to form a sporangium which at maturity contains numerous uninucleate spores, capillitia, columella, peridium, stalk, and hypothallus.

In general, fungi grow where suitable nutrients, environment, and space are provided, and at times in habitats unsuitable for other forms of life. One fungal spore germinates to form a colony which is capable of producing millions of reproductive cells. This aggregation of like reproductive cells occurs because of the morphological development of the species. Fungi having similar nutritional and environmental requirements will be found in the same or similar ecological areas.

5.b. As the variation in organisms increases, the probability of an increase in structural organization becomes higher through differentiation from single-celled organisms via colonial organisms into multicellular organisms.

In multicellular fungi, cell structure diversity is also found. Morphological size increases are not related to a continued increase in structural differentiation. Depending on habitat in which the isolate is growing, most fungi are colony forming species. A mycelial colony of Fusarium moniliforme can be very complex in cell structure and the complexity increases as the colony ages and continues maturation. One of the largest fungal species in size is Calvatia gigantea with one fruit body possibly weighing over 200 lbs. However, cell differentiation in Calvatia at maturity is quite limited. The single cell yeast Saccharomyces cerevisiae keeps the the brewing and baking industries in business. For that single celled species, many thousands of isolates are maintained for the production of different characteristics in the commercial end products. Peach leaf curl, Taphrina deformans, has very few cells, however, the cells found in and on the host leaf are highly differentiated. Few cells are required to support the growth of the T. deformans asci and ascospores found on the peach host leaf. The many insect fungal parasites, such as Stigmatomyces ceratophorus, are also very limited in their cell numbers, however, the cells present are quite diversified in form and function. Many fungal species are host specific in their ability to parasitize and carry out their own life cycle, however, their cell diversity is not complex. The physiology of these fungi is highly complex and specialized beyond their multicellular diversification.

5.c. As structural organization increases, the complexity of interactions necessarily increases.

The structural organization of a fungal cell equates in form and function at the electron microscopic level to cells of other living systems composed of more densely organized cells and highly specialized tissues. With an increase in the number of types of fungal reproductive cells per species, an increase in reproductive efficiency occurs, but also a greater limitation in habitats or hosts suitable for fungal survival and growth also occurs. The importance of environmental stress decreases but the habitat is limited. Reproductive spore diversity increases the specialty of interactions or sites suitable for spore germination and survival, but those growth sites are more specific and limited. The alternate host barberry can be eliminated from the environment for wheat rust. Puccinia graminis will not survive in the absence of barberry even though the other host, wheat, is present.

The birds nest fungus Cyathus striatus has highly evolved tissue types and structural forms to equate in appearance a minature bird's nest complete with eggs. Methods of dispersal are more complex due to structural developments in the methods of interaction with environmental parameters and neighboring plants or animals. However, the basidiospore is the principle reproductive cell in Cyathus which germinates and produces hyphae similar to basidiospores of other representatives found in the Basidiomycetes class of fungi.

5.d. For any given organism, increase in size demands the uptake of additional resources. This uptake will have a maximal value for any given size, construction, physiology and environment. Further growth then depends either on increased resource capture, a change in organization, a change in basic physiology or reproduction.

Young, actively metabolizing pathogenic or saprobic fungal cells effectively take up required nutrients from their environmental resources. As the cells age and become increasingly vacuolated, reducing the level of metabolism, or as cells become further separated from their nutrient source due to increased density of fungal colony growth, uptake of nutrients is reduced, and the colony reaches maturation and the spore production stage. Frequently the fungal colony or the fructification of the species is entirely dedicated to spore production. Often the spores are quite isolated from harsh environmental conditions by spore and fruit body structure, and then the spores do not integrate with the environment until suitable germination conditions occur. Fungi are dependent plants, receiving all nutrients to support growth and development through absorption from the environment.

5.e. As more complex aggregations are formed, these generate more properties which allow them to be considered at a simpler level of organization than the integral of their components and processes.

With an increase in density of fungal colony growth and an increase in cellular differentiation in fungal structures such as sclerotia, stroma, basidiocarps, and ascocarps, cells adjacent to each other in the tissues have increased dependence on each other for nutritional requirements and physical support. Cells in fungal tissue become somewhat more specialized and require their neighbors for support and survival. A greater role in support and translocation of required nutrients is found in cells closer to the substrate or nutrient source. Pseudoparenchyma cells in the stipe of a mushroom are more tubular and elongated, and translocate greater quantities of water and dissolved organic and inorganic substances than tramal cells found in the pileus or cap. However, any viable cell in a basidiocarp can be asceptically transferred to suitable media for regeneration of a new complete basidiocarp if that particular basidiomycete species is capable of growing to maturity _in vitro_.

5.f. At the highest levels of specialization, structural and functional complexity of an organism may be reduced by an obligatory association with another organism, the complexity of the organism is replaced by the complexity of the relationships between the organisms.

Obligate fungal pathogens in plants can survive only by parasitizing another organism or host. Fungal parasites tend to have a reduced number of cells in a host, particularly those fungi that parasitize man and animals, compared with fungal species growing as saprophytes in nature. The saprobes have large supporting vegetative mycelial structures growing submerged in the soil or substrate that cover at times a wide area of the habitat. Mycelial mats growing below the ground surface can be measured in undisturbed meadow areas, similar to the coasts of England, with mat diameters covering many acres and with an age to the fungal system from one to 200 years or more. For example, the fairy ring fungus, _Chlorophyllum molybdites_, produces basidiocarps at the periphery of the mycelial mats, with the entire complex structure originating from one basidiospore that germinated many years earlier.

With fungal pathogens, the complexity of the host parasite relationships is highly specific. Facultative human fungal pathogens such as _Sporothrix schenckii_ tend to have a reduced cell differentiation when found in a patient. Systemic fungal growth in man is at a lower growth rate, however, treatment methods involve massive doses of chemotherapy over a long period of time with unpredictable effectiveness. The same fungal species grown in vitro saprophytically develops additional fungal cell structures that aid in species identification, and respond to chemotherapeutic compounds at lower concentrations than in vivo. Some human systemic species such as Coccicioides immitis and Paracoccidioides brasiliensis are dimorphic with only a simple vegetative yeast phase found in many and a delicate multicellular complex when grown aerobically in vitro at at 24 C temperature. Chemotherapy for terminal diseases in man has created new habitats for microorganisms, particularly bacteria and fungi, that normally are not pathogenic. The secondary invaders advance in the patient at an alarming speed and become uncontrollable within hours or a few days. Hundreds of opportunistic species to date have been identified at autopsy.

6. Disturbance to the environment (i.e., biological systems and/ or their resources) will lead to a multitude of sequential changes in the total ecological system which may, or may not, be important.

All fungi are dependent plants and totally integrate with their environment. Any change in the environment will create a change for the species which may be severe enough to eradicate the species from the environment that originally supported the organism.

6.a. Perturbation to the environment will lead to a multitude of sequential changes in the ecosystem. The effects of a perturbation will vary with its intensity, frequency, and predicability.

Many studies have been conducted with fungi and other microorganisms aboard balloons, earth satellites and high altitude sounding rockets for evaluations of environmental conditions of space flight missions. In controlled experiments on Apollo lunar flights, vegatative cells of two yeast species and conidia of two filamentous fungal species were exposed to many specific space flight parameters, including weightlessness, HZe particles, space vacuum, UV light wavelengths at 254, 280, and 300 nm at specific energy levels. All parameters were specifically monitored and compared with ground controls. A spectrum of changes were found in the space exposed fungi according to exposures. Variations examined that registered change included viability, phenotypic counts, growth rates, dry cell weights, growth dynamics and colony morphology, cell structure changes, pathogenicity and drug reactivity, host enzyme reactivity, nutritional requirements, enzyme production, host foreign body reactions, cytogenetics, and cytological changes. An initial change in space produced a spectrum of reactions. Test fungi involved in the Apollo studies included Saccharomyces cerevisiae, Rhodotorula rubra, Trichophyton terrestre and Chaetomium globosum. On earth in nature constant change in the environment also produces a continual spectral change of qualities and characteristics found in the fungi and in other microorganisms.

6.b. Predictable time-dependent perturbations select for the formation of resistant stages in the life cycles of organisms.

Environmental quality change initiates change in fungal reproductive spores. Sexual spores form toward the end of a fungal life cycle while asexual spores frequently referred to as "summer spores" develop over a greater portion of life cycles of most fungi, generally before meiotic spores develop. The powdery mildew fungi belonging to the Erysiphaceae and the downy mildew fungi belonging to the Peronosporaceae easily demonstrate this spore concept, however, species from all major classes of the fungi also present this basic life cycle form. Seasonal change is time dependent and with these changes there occurs change in temperature, light intensity and duration, moisture, and nutrient availability which are factors influencing sexual and asexual spore production as well as morphological development in fungi.

6.c. Disturbances result in the mortality of many individuals, but occur at such time scales and intensities that natural selection leads to component species of the ecosystem being adapted to recover from the disturbance.

Forest fires, land slides, and floods have denuded a habitat of all plant and animal species. A recovery from the devastation introduces new plant and animal species to the region and with them new fungal and other microbial pathogens representing all previously lost fungal classes. Fossilized leaves of extinct plant species found in coal deposits indicate microbial species were also prevalent in past histories to cause abnormalities in their hosts. Soil sterilized by chemical or steam methods is first recolonized by the microbes before larger inhabitants return. The intestinal system of a living human or animal is constantly under microbial population shifts that reflect the continual change in the metabolism and diet of the individual. Any habitat examined for fungal populations will identify continual and frequent change in dominant species, density of individual species, and diversity in represented species. These changes are produced by the species themselves, by their interactions, and by the most subtile changes in the environment.

6.d. Catastrophies occur at such rare intervals, or with such intensity, causing complete or almost complete mortality, that the evolutionary effects on the pre-existing species are minimal and the resulting ecosystem is unpredictable. The extinction of pre-existing species and the environmental changes associated with the catastrophy free new niches for colonization and hence evolution may be stimulated.

Environmental catastrophies will leave behind new quantities and qualities of nutrients, and at times climatic changes also result. Microbes are transported into the newly created environment by air, water, soil, and by the new hosts that may recolonize the new ecosystem. The same ecological parameters of the community, its development, and interspecific relations will direct the development and progression of the recreated ecosystem to produce predictable results depending on the balances and checks associated with the new microbial species.

7. Pure interactions do not exist in nature.

Fungi present many specific and highly specialized interactions that involve only two entities. The male and female or + and - gametes of each species are specific for each species to form the zygote cell of each species. Many obligate pathogens are host species specific. The many diverse lichens are associations of a specific fungal mycobiont and a specific algal phycobiont that forms a mutualistic symbiosis from which both organisms benefit. However, the interactions, regardless of the degree of specialization, require a substrate or a favorable environment in which to accomplish the interaction.

7.a. As ecological processes are heavily dependent upon other processes including the feedback of themselves, no process can be analysed in isolation. Thus, any study is an approximation but the degree of approximation may be excellent if the effects of unmonitored processes are small or, sometimes, constant.

A quantative and qualitative analysis of data collected in nature on microbial ecology is quite subjective and filled with biased interpretation. Conducting a study to produce reliable data, the number of test parameters and parameters of unknown proportions should be reduced to the lowest possible minimum while controls included in the experimentation should be comprehensive and quite extensive. In vitro studies give base line data and information that can be utilized and examined in environmental study. Generation time in microbial populations and individual microbial species is rapid and subject to rapid change which soon becomes uncomprehensible in a natural sètting. Each test parameter must be studied and tested extensively on an individual basis with microbial species before any meaningful interpretation can even be suggested in a specific natural environmental habitat.

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